527 Rec'd PCT/PTC 10 NOV 2000

FORM PTO-1390 (REV. 5-93) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER 10191/1565 09/674984
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371	U.S. APPLICATION NO. (If known, see 37 CFR 1.5)

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED:
PCT/DE00/00749	(13.03.00) 13 March 2000	(12.03.99) 12 March 1999

TITLE OF INVENTION
A DEVICE AND METHOD FOR DETERMINING THE LATERAL UNDERCUT OF A STRUCTURED SURFACE LAYER

APPLICANT(S) FOR DO/EO/US
Volker BECKER, Franz LAERMER and Andrea SCHILP

Applicants herewith submit to the United States Designated/Elected Office (DO/EO/US) the following items and other information

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2))
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U S.C. 371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3))
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)) (unsigned).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12 ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included
13. ☒ A **FIRST** preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information: International Search Report, and PCT/RO/101.

EXPRESS MAIL NO.: EL 302 702 035

U.S. APPLICATION NO. (if known, see 37 C.F.R.1.5) 09/674984	INTERNATIONAL APPLICATION NO. PCT/DE00/00749	ATTORNEY'S DOCKET NUMBER 10191/1565

529 Rec'd PCT/PTO 16 NOV 2000

		CALCULATIONS	PTO USE ONLY
17. ☒ The following fees are submitted: **Basic National Fee (37 CFR 1.492(a)(1)-(5)):** Search Report has been prepared by the EUROPEAN PATENT OFFICE or JPO .... $860.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) ...... $690.00 No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) .... $710.00 Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO .... $1,000.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $100.00			
ENTER APPROPRIATE BASIC FEE AMOUNT =		$ 860	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).		$	

Claims	Number Filed	Number Extra	Rate		
Total Claims	26 - 20 =	6	X $18.00	$108	
Independent Claims	2 - 3 =	0	X $80.00	$ 0	
Multiple dependent claim(s) (if applicable)			+ $270.00	$	
TOTAL OF ABOVE CALCULATIONS =				$ 968	
Reduction by ½ for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).				$	
SUBTOTAL =				$968	
Processing fee of $130.00 for furnishing the English translation later the ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$ 968	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$	
TOTAL FEES ENCLOSED =				$ 968	
				Amount to be: refunded	$
				charged	$

a. ☐ A check in the amount of $__________ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 11-0600 in the amount of **$968.00** to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 11-0600. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

By: [signature] (Reg. No. 41,172)

Richard L. Mayer
SIGNATURE

SEND ALL CORRESPONDENCE TO:
Kenyon & Kenyon
One Broadway
New York, New York 10004

Richard L. Mayer, Reg. No 22,490
NAME

11/15/00
DATE

FORM PTO-1390 (REV. 5-93)	U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	529 Rec'd PCT/PTC 10 NOV 2000 ATTORNEY'S DOCKET NUMBER 10191/1565
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		U.S APPLICATION NO. (If known, see 37 CFR 1.5) 09/674984

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED.
PCT/DE00/00749	(13.03.00) 13 March 2000	(12.03.99) 12 March 1999

TITLE OF INVENTION
A DEVICE AND METHOD FOR DETERMINING THE LATERAL UNDERCUT OF A STRUCTURED SURFACE LAYER

APPLICANT(S) FOR DO/EO/US
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EXPRESS MAIL NO.: EL302702035

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529 Rec'd PCT/PTC 10 NOV 2000

[10191/1565]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s)	:	BECKER et al.
Serial No.	:	To Be Assigned
Filed	:	Herewith
For	:	A DEVICE AND METHOD FOR DETERMINING THE LATERAL UNDERCUT OF A STRUCTURED SURFACE LAYER
Examiner	:	To Be Assigned
Group Art Unit	:	To Be Assigned

Assistant Commissioner
for Patents
Washington, D.C. 20231

PRELIMINARY AMENDMENT

SIR:

Please amend the above-identified application before examination as follows:

In The Specification:

On page 1, line 1 delete "Background Information" and insert --Field Of The Invention--.

On page 1, line 3, before "invention" insert --present--.

On page 1, line 4, delete "according to the species of the independent claims".

On page 1, line 5 insert --Background Information--.

EL302702035

On page 1, line 17, insert --Summary Of The Invention--.

On page 1, line 18, change "The objective" to --An object--.

On page 1, line 23, delete "Advantages of the Invention".

On page 1, line 26, delete "having the characterizing features of the".

On page 1, line 27, delete "independent claims".

On page 2, delete lines 9-10.

On page 4, delete lines 8-16 and insert:

--Brief Description Of The Drawings

Figure 1 depicts a cutaway view of a layer arrangement having a structured surface layer.

Figure 2 depicts a top view of Figure 1.

Figure 3 depicts a further specific embodiment of the layer arrangement according to Figure 1 having supplemental external assemblies.

Detailed Description--.

On page 4, line 22, before "Patent" insert --Published--.

On page 4, line 22, change "198 47 455.5" to --No. 198 47 455--.

On page 9, line 10, change "Essential" to --Apparent--.

On page 9, line 20, delete "must".

On page 9, line 20, change "cover" to --covers--.

On page 11, line 1, change "Patent Claims" to --What Is Claimed Is:--.

In the Claims:

Please cancel claims 1-22, without prejudice. Please also enter the following new claims.

23. (New) A device for determining an extent of an at least locally lateral undercut of a structured surface layer on a sacrificial layer, comprising:

at least one passive electronic component arranged on the structured surface layer and for determining a physical measured quantity that is proportional to the extent of the lateral undercut.

24. (New) The device according to claim 23, wherein the physical measured quantity corresponds to one of:

a capacitance,

one of an absorbed intensity and an emitted intensity of an electromagnetic emission,

one of an absorbed frequency and an emitted frequency, and

one of an absorbed frequency spectrum and an emitted frequency spectrum of the electromagnetic emission.

25. (New) The device according to claim 24, wherein:

the one of the absorbed frequency and the emitted frequency corresponds to a resonance frequency.

26. (New) The device according to claim 23, further comprising:

at least one transmitter for emitting a first signal;

at least one receiver for detecting a second signal, the at least one passive electronic component interacting with the first signal and one of generating the second signal and transforming the first signal into the second signal.

27. (New) The device according to claim 26, wherein the physical measured quantity is determined from one of:

the second signal, and

a difference between the first signal and the second signal.

28. (New) The device according to claim 26, wherein:

the at least one transmitter and the at least one receiver are integrated in an assembly.

29. (New) The device according to claim 28, wherein:

the assembly includes a processing unit.

30. (New) The device according to claim 26, wherein:

the at least one transmitter is at the same time also the at least one receiver.

31. (New) The device according to claim 26, wherein:

the first signal includes one of:

a first voltage applied to the at least one passive electronic component,

an intensity of an electromagnetic emission,

a high-frequency power output that is emitted one of continuously and in pulses and emitted into the at least one passive electronic component, the high-frequency power output having one of a preestablished frequency and a preestablished frequency spectrum, and

a sequence of one of chirped high-frequency pulses and broadband noise pulses of the electromagnetic emission, and

the second signal includes one of:

a second voltage,

one of an absorbed intensity and an emitted intensity of the electromagnetic emission, and

one of a frequency and a frequency spectrum of the electromagnetic emission.

32. (New) The device according to claim 31, wherein:

the frequency of the electromagnetic emission corresponds to a resonance frequency.

33. (New) The device according to claim 23, wherein:

the at least one passive electronic component includes a coil delineated out in the structured surface layer and including a first coil end and a second coil end,

the coil and a base layer arranged with respect to the structured surface layer and the sacrificial layer form a capacitor having a capacitance proportional to the extent of the lateral undercut.

34. (New) The device according to claim 33, wherein:

the coil forms an oscillating circuit having a resonance frequency f_0, and a change Δf_0 is proportional to the extent of the lateral undercut.

35. (New) The device according to claim 33, wherein:

a plated through-hole extends through the sacrificial layer,

the plated-through hole connects one of the first coil end and the second coil end to the base layer.

36. (New) The device according to claim 33, wherein:

at least one of the first coil end and the second coil end is dimensioned in an extent thereof such that a complete undercut of the at least one of the first coil end and the second coil end does not occur.

37. (New) The device according to claim 23, wherein:

the structured surface layer, at least in an area of the at least one passive electronic component, is separated from a base layer by the sacrificial layer.

38. (New) The device according to claim 37, wherein a structure of the base layer corresponds to one of:

a material including one of silicon and polysilicon, and

a silicon wafer.

39. (New) The device according to claim 23, wherein:

the structured surface layer, at least in an area of the at least one passive electronic component, is at least weakly electrically conductive and is composed of one of silicon, polysilicon, a surface-metallized silicon, a doped silicon, a surface-metallized polysilicon, and a doped polysilicon.

40. (New) The device according to claim 23, wherein:

the sacrificial layer, at least in an area of the at least one passive electronic component, is electrically insulating and includes a silicon oxide layer.

41. (New) The device according to claim 23, wherein:

the structured surface layer includes trenches that extend in depth down to the sacrificial layer.

42. (New) The device according to claim 41, wherein:

the trenches border a structure, to be undercut, in the structured surface layer.

43. (New) A method for determining an extent of a lateral undercut of a structured surface layer on a sacrificial layer, comprising the steps of:

performing a first etching operation to provide at least locally to the structured surface layer a structure including trenches, wherein the first etching operation includes the step of:

locally additionally delineating at least one passive electronic component out of the structured surface layer;

performing a second etching operation that begins from the trenches and generates at least locally the lateral undercut of the structured surface layer;

undercutting the at least one passive electronic component in response to the undercutting of the structured surface layer; and

in response to the undercutting of at least one of the structured surface layer and the at least one passive electronic component, causing the at least one passive electronic component to determine a physical measured quantity proportional to the extent of the lateral undercut.

44. (New) The method according to claim 43, wherein:

the step of performing the first etching operation occurs through a masking.

45. (New) The method according to claim 43, further comprising the step of:

applying the sacrificial layer on a base layer.

46. (New) The method according to claim 43, wherein:

the step of delineating occurs through an etching of the trenches.

47. (New) The method according to claim 43, further comprising the step of:

delineating a coil out of the structured surface layer as the at least one passive electronic component.

48. (New) The method according to claim 47, further comprising the steps of:

in response to an undercut of the coil, measuring a resonance frequency of an oscillating circuit formed on the basis of the coil; and

determining from the resonance frequency the extent of the lateral undercut.

<u>In The Abstract</u>:

Delete the Abstract and insert:

--<u>Abstract Of The Disclosure</u>

A device and a method for determining the extent of an at least locally lateral undercut of a structured surface layer on a sacrificial layer. The structured surface layer for this purpose locally has at least one passive electronic component, using which a physical measured quantity can be determined, which is proportional to the extent of the lateral undercut. The method for generating this device proposes, initially on the structured surface layer in a first etching method, to provide the surface layer at least locally with a structuring having trenches and, in a second etching method, proceeding from the trenches, to undertake at least locally a lateral undercut of the structured surface layer. In this context, in the first etching method on the surface layer, locally at least one passive electronic component is additionally delineated out, which in response to a subsequent undercutting of the surface layer is also undercut. The physical measured quantity is determined without contact, preferably by sending an electromagnetic emission into the passive component.--.

<u>Remarks</u>

This Preliminary Amendment cancels original claims 1-22, without prejudice, in the underlying PCT Application No. PCT/DE00/00749. This Preliminary Amendment also adds new claims 23-48. The new claims do not add new matter to the application, but do conform the claims to U.S. Patent and Trademark Office rules.

The amendments to the specification and abstract are to conform the

specification and abstract to U.S. Patent and Trademark Office rules. The amendments to the specification and abstract do not introduce new matter into the application.

The underlying PCT application includes a Search Report dated July 19, 2000, a copy of which is submitted herewith.

Applicants assert that the present invention is new, non-obvious, and useful. Consideration and allowance of the claims are requested.

Respectfully submitted,

KENYON & KENYON

By: [signature]

Dated: 11/10/00

By: Richard L. Mayer

Richard L. Mayer
Reg. No. 22,490

One Broadway
New York, NY 10004
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2/PRTS

09/674984
529 Rec'd PCT/PTO 10 NOV 2000

[10191/1565]

A DEVICE AND METHOD FOR DETERMINING THE LATERAL UNDERCUT OF A STRUCTURED SURFACE LAYER

Background Information

The invention relates to a device and a method for determining an at least local lateral undercut of a structured surface layer according to the species of the independent claims.

It is known to etch micromechanical surface structures in a silicon layer in hydrofluoride acid vapor and, to achieve an undercut of a structured surface layer of silicon, to apply a sacrificial layer of silicon dioxide under the surface layer to be structured. In this context, the hydrofluoride acid vapor, in etching the sacrificial layer, effects a purely time-controlled undercut of the structured surface layer, so that the specific undercut width achieved in the sacrificial layer, for example, to bring about the defined exposure of free-standing sensor structures in the surface layer, is not directly measurable in the course of the hydrofluoride acid vapor undercut, or cannot be monitored during the etching. Therefore, the permanent danger exists of inadvertently etching too briefly or too long. In particular, an etching lasting too long can lead to the destruction of structures on a wafer, for example, by detaching them from the substrate.

The objective of the present invention, therefore, was to make available a method and a device suitable for carrying it out, which make it possible, in an ongoing way, to measure the achieved undercut width and the extent of the undercut of a structured surface layer, during the undercutting process.

Advantages of the Invention

In contrast to the related art, the method according to the present invention, along with the device according to the present invention, having the characterizing features of the independent claims has the advantage that it makes it possible to determine the extent of the lateral undercut of a structured surface layer by etching a sacrificial layer, in an ongoing manner, in situ, i.e., during the undercutting, as a function of time, and therefore to be able to

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monitor and adjust the undercut.

For this purpose, at least one passive electronic component is delineated out from the surface layer, in some areas as a supplement, the component also being undercut when the surface layer is undercut and, in response to the undercutting, the component determining a physical measured quantity proportional to the extent of the undercut.

Advantageous refinements of the invention are yielded from the measures cited in the subclaims.

Thus it is very advantageous if the physical measured quantity is a capacitance, an absorbed or emitted intensity of an electromagnetic emission, an absorbed or emitted frequency, in particular a resonance frequency, or an absorbed or emitted frequency spectrum of an electromagnetic emission. In this context, it is advantageous if a first signal is emitted by at least one transmitter, the passive electronic component interacting with the first signal, a second signal being generated or the first signal being transformed into a second signal, which in turn is detected by at least one receiver. The physical measured quantity and thus the undercut proportional thereto are then determined from the second signal or from the difference between the first and the second signal.

In this context, the transmitter and receiver, in a very advantageous manner, are located outside the actual etching chamber and thus remain protected from etching corrosion, in particular, from aggressive etching gases such as hydrofluoride acid vapor, ClF_3, XeF_2, and the like. Thus, in a way that is also very advantageous, it is possible to do without a costly interconnecting and contacting of the passive electronic component. The interaction of the passive component and the transmitter or receiver thus takes place, advantageously, without contact.

Furthermore, it is particularly advantageous if the transmitter and receiver are integrated in one assembly, in particular a processing unit and/or the transmitter is also a receiver. In particular, in the latter case, characteristic electrical parameters of the transmitter, which react to changes in an electromagnetic radiation field, such as internal voltages, currents, or phases between internal voltages and currents, can very expediently be detected or evaluated in a

simple manner.

Particularly suitable as a first signal is an electrical voltage coupled or applied to the passive electronic component; an irradiated or introduced intensity of an electromagnetic emission; (particularly advantageously) a high-frequency power output, irradiated or introduced into the passive electronic component, continuously or in pulses, the high-frequency power output having a preestablished frequency or preestablished frequency spectrum; or a sequence of chirped high-frequency pulses of an electromagnetic emission.

Similarly, it is advantageous if the second signal is also an electrical voltage, an absorbed or emitted intensity of an electromagnetic emission, an absorbed or emitted frequency, in particular, a resonance frequency, or a frequency spectrum of an electromagnetic emission.

Furthermore, it is particularly advantageous if the passive electronic component is a coil, additionally delineated out of the structured surface layer that is to be undercut at least locally, the coil, along with a base layer located underneath it, simultaneously forming a capacitor, in whose operation the sacrificial layer functions as a dielectric. Capacitance C of this capacitor is then proportional to the extent, to be determined, of the lateral undercut of the structured surface layer. The coil and the capacitor, formed on the basis of the coil and the base layer underneath it, thus represent an LC-oscillating circuit having a resonance frequency f_0, whose change Δf_0 is then proportional to the extent, to be determined, of the locally lateral undercut of the surface layer. In this context, at least one of the two coil ends of the coil, that is additionally delineated out as a passive electronic component, is advantageously dimensioned in its extension such that a complete undercut of the coil end does not occur. Therefore, the coil remains permanently attached to the base layer at least on one side and, for example, does not collapse.

Particularly suitable as material for the base layer is silicon or a silicon wafer. The surface layer is advantageously also made of silicon or polysilicon, which, for example, to improve the electrical properties, can be doped and/or metallized on the surface. Well-suited as the sacrificial layer, at least in the area of the passive electronic component and of the coil, is an electrically insulating material such as silicon oxide.

The method of the present invention is particularly well suited for a defined undercut, in particular in a vapor phase of hydrofluoride acid vapor or in a gas phase, for example, using ClF_3, BrF_3, or XeF_2, and thus for generating free-standing sensor structures in the structured surface layer. As a rule, the method is not suited for use in liquid etching media such as aqueous hydrofluoric acid, since, for example, the sending of a high-frequency emission into an electrolyte is difficult due to strong radiation damping.

Drawing

Exemplary embodiments of the present invention are explained in greater detail on the basis of the drawings and in the description below. Figure 1 depicts a cutaway view of a layer arrangement having a structured surface layer, Figure 2 depicts a top view of Figure 1, and Figure 3 depicts a further specific embodiment of the layer arrangement according to Figure 1 having supplemental external assemblies.

Exemplary Embodiments

Figure 1 depicts a layer arrangement having a structured surface layer 23, a sacrificial layer 21, and a base layer 20. Surface layer 23 is made of silicon or polysilicon, which is metallized on the surface, sacrificial layer 21 being made of silicon oxide, and base layer 20 being constituted by a silicon wafer. A design of this type has already been described, for example, in the German Patent Application 198 47 455.5. Furthermore, at least one passive electronic component 31 is locally delineated out from surface layer 23 in the form of a coil 30, coil 30 having a first coil end 13 and a second coil end 12 as well as coil windings 14, which are separated from each other via trenches 15, delineated out in surface layer 23 and extending in depth down to sacrificial layer 21. First coil end 13 is connected to base layer 20 via a plated through-hole 22, base layer 20 being electrically conductive. Coil 30 having inductance L thus constitutes, along with base layer 20, a capacitor having a capacitance C, sacrificial layer 21 functioning as dialectric.

Furthermore, at least one structure 11, to be undercut or exposed, is delineated out from structured surface layer 23 through trenches 15', trenches 15' also extending in depth down to sacrificial layer 21. In practice, a multiplicity of potentially different structures 11 are

delineated out from surface layer 23, whereas a few passive electronic components 31 at most are usually sufficient to determine the extent of the lateral undercut. The shape of structure 11, in this context, is not subjected to any limitation. In this context, it can be a structure 11, to be exposed, in the shape of a micro oscillating mirror, a sensor, or only an area of surface layer 23. In particular, structure 11, in this context, does not have to be surrounded by trenches 15', it rather being sufficient if a lateral undercut of structure 11 is made possible by only one trench 15', which, for example, can also be configured as a hole.

Figure 2 depicts a top view of Figure 1, coil 30 in this case being located, by way of example, in the immediate vicinity of structure 11, and structure 11 being a plate 11 to be undercut completely or partially, the extent of the undercut being determined with the assistance of passive electronic component 31, i.e., coil 30. In addition, first and second coil ends 12, 13 are, in each case, configured so as to cover a large surface opposite coil windings 14, in order to avoid a complete undercut of at least one of coil ends 12 or 13. The dimensioning of coil ends 12, 13, the number of coil windings 14, the width of trenches 15 and 15', and the shape of coil 30, which is executed in Figure 2 in the shape of a right-angle meander only for purposes of illustration, follow, in the individual case, from the lateral extent of the undercut, to be determined. With respect to these variables, Figures 1 through 3 should not be understood as providing a standard. In particular, the windings of coil 30 can also be configured in a spiral shape, the surfaces occupied by coil ends 12, 13 can be significantly larger than the surface of structure 11, and the width of trenches 15 can be comparable to the width of structure 11. The suitable dimensioning of the individual components can be stipulated by the worker skilled in the art in the concrete case, on the basis of simple reflections and trials. In this context, the dimensioning also depends, for example, on the frequency range in which the work is to be done.

Figure 3 depicts one refinement of Figure 1 having further external assemblies. In this context, a first signal is emitted from external transmitter 43, the first signal interacting with passive electronic component 31, i.e., coil 30, and as a result, the first signal is transformed into a second signal, or a second signal is emitted. Receiver 44 then receives this second signal. In this context, transmitter 43 and receiver 44 can operate either continuously (simultaneously transmitting and receiving) or alternately (alternately transmitting and receiving). Furthermore, a correlator 45 is provided, which determines the physical measured

quantity in a generally known manner from the second signal or from the difference between the first and the second signal. In Figure 3, accordingly, transmitter 43, receiver 44, and correlator 45 constitute a processing unit 40, which sits outside the silicon wafer and interacts via electromagnetic emissions, without contact, with coil 30 and with the oscillating circuit formed by coil 30 and base layer 20. Processing unit 40 can therefore also be arranged outside the actual etching installation and, there, is not exposed in particular to the corrosion of an aggressive etching medium. Therefore, an interconnection with coil 30 is not necessary.

In Figure 3, the manner is also indicated in which an undercut of structured surface layer 23, through the etching of sacrificial layer 21, emerges from etching areas 50 and 50' at the base of trenches 15, 15', for example, in a well-known manner, in hydrofluoric acid vapor.

Specifically, in the exemplary embodiment discussed according to Figure 1, a silicon dioxide layer is first applied as sacrificial layer 21 on a silicon wafer, which functions as a base layer 20. On this sacrificial layer 21, a surface layer 23 made of silicon or polysilicon is then applied, which is metallized on the surface. Subsequently, surface layer 23, in a generally known manner, is structured using a masking, and trenches 15 and 15' are etched into surface layer 23, which extend in depth down to sacrificial layer 21. Trenches 15', in this context, surround at least one structure 11, to be undercut and especially to be exposed. At the same time, using the etching process for structuring surface layer 23, one or a plurality of passive electronic components 31, in the form of a coil 30, is etched into surface layer 23 and is delineated out from it, so that a plurality of coil windings 14 is executed in the silicon of surface layer 23, which are arranged on the same sacrificial oxide type, i.e., the same sacrificial layer 21, as structures 11 to be exposed.

First coil end 13 or second coil end 12 of coil 30 can also be electrically connected to base layer 20 using a plated through-hole 22 in the form of a contact hole (see Figure 1). Alternatively, at least one of the two coil ends 12, 13 can also be widened to the point that it is dependably not entirely undercut during the undercutting of structure 11 to be exposed, so that coil 30 remains attached, at least on one side, on sacrificial layer 21 (see Figure 3). Furthermore, it is also possible to widen both coil ends 12, 13, so that neither is completely undercut during the undercutting. In the event that one of coil ends 12, 13 is not widened and is completely undercut in the undercutting of structure 11, to be exposed, it is also possible to

retain a construction of coil 30 that is self-supporting after the termination of the undercutting, if the respective other coil end is widened or, as is particularly preferred, it is connected to base layer 20 by a plated through-hole 22. A combination of a widened coil end along with a coil end connected to base layer 20 via a plated through-hole 22 has proven to be particularly expedient.

A capacitor having capacitance C distributed over the length of coil windings 14 is formed, in the direction of base layer 20, by the arrangement of coil windings 14, having the silicon oxide of sacrificial layer 21 underneath. Coil 30, as an electrical conductor, at the same time has an inductance L, so that in any case an oscillating circuit arises whose resonance frequency f_0, as a result of inductance L and capacitance C, is given as $f_0 = \frac{1}{\sqrt{LC}} * \frac{1}{2\pi}$.

In one preferred embodiment, the surface of surface layer 23 in the area of coil 30 is metallized, for example, using aluminum, AlSiCu, or AlSi, this metallization also being able to function as a contact material for structure 11. As a result of the metallization, the ohmic resistance of coil windings 14 is significantly reduced and, therefore, the highest possible resonance quality of the generated LC oscillating circuit is achieved. Thus a sharp definition of the resonance frequency of the generated oscillating circuit is assured through high resonance quality, on the basis of minimal electrical damping.

On the basis of the relative permittivity of silicon dioxide ε_{oxide} of 3.88 in comparison to that of air ε_{air} of 1, capacitance C of capacitor diminishes in proportion to the degree that sacrificial layer 21 under coil 30, or coil ends 14 and/or 13, is etched away through a lateral undercut in hydrofluoric acid vapor and, in this context, is replaced by air or hydrofluoric acid vapor. Sacrificial layer 21 as a dielectric thus constantly changes its effective relative permittivity during the undercutting, the effective relative permittivity generated as a function of the undercut being proportional to the lateral extent of the undercut of coil 30. For the changing of capacitance C of the capacitor formed by coil 30 and base layer 20, the following applies:

$$C = \varepsilon\varepsilon_0 \frac{A}{d} \quad and \quad \Delta C = \varepsilon_0 \frac{\Delta A}{d}\left(\varepsilon_{oxide} - 1\right).$$

In this context, ΔA designates the surface of sacrificial layer 21 removed by the undercutting under coil 30 and d designates the distance between coil 30 and base layer 20, i.e., the thickness of originally existing sacrificial layer 21.

The measured lateral extent of the undercut of coil 30 is therefore a measure for the lateral extent of the undercut of structure 11.

The change of capacitance ΔC of the oscillating circuit is in turn very precisely measurable through change Δf_0 of resonance frequency f_0 of the LC oscillating circuit, the following being valid in the first approximation:

$$\Delta f_0 = -\frac{1}{2}\frac{\Delta C}{C} f_0.$$

In this context, the metrological recording of resonance frequency f_0 of the oscillating circuit or its change Δf_0, in response to progressive undercutting, can take place in a multitude of well-known ways. Particularly suitable is the resonant absorption and reradiation of an irradiated or introduced high-frequency emission. For this purpose, for example, in accordance with Figure 3, using a so-called "grid-dipper" as processing unit 40, a high-frequency emission, in hydrofluoric acid vapor, is emitted into the etching device used for this purpose during the undercutting, the frequency position of the etching device being varied manually or automatically. In the case of automatic variation, the terms "frequency sweep" or "wobbling" are used. In the resonance case, i.e., if the frequency applied or irradiated from outside coincides with the resonance frequency of the oscillating circuit, the oscillating circuit then effects a change of least one characteristic electrical or physical measured quantity, which is detected. Thus a resonance absorption by passive electronic component 31, i.e., by the LC oscillating circuit formed from coil 30 and base layer 20, from an external high-frequency radiation field on the emitter side, i.e., in transmitter 43, results in a change in voltages, currents, or phases between currents and voltages, which can be detected as measured quantities in transmitter 43 itself. Well-suited for this purpose is, for example, the

grid current of an oscillator valve (electron valve) functioning as a high-frequency generator generating the irradiated or introduced high-frequency emission, the term "grid dipper" for this measuring device deriving therefrom, since the grid current of an oscillator valve of this type breaks (dips) in a very measurable way in the case of resonance with regard to an external oscillating circuit.

However, corresponding electrical quantities also arise in the case of transistor oscillators, if an external oscillating circuit is met in a resonant fashion by the irradiated high frequency emission and, in this context, if it takes on energy from the radiation field. Essential in the exemplary embodiments discussed is always the change in the radiation field brought about by a resonance absorption, which can then be detected in a multiplicity of well-known ways and, for example, can be precisely determined with respect to frequency.

A further exemplary embodiment, particularly for determining the resonance frequency of the oscillating circuit, provides for emitting into the oscillating circuit formed on the basis of coil 30 so-called "chirped" high-frequency pulses from transmitter 43 of processing unit 40 in accordance with Figure 3, i.e., high-frequency pulses, whose frequency rapidly changes in accordance with a preestablished time function (for example, linear). In this context, the chirped high-frequency pulse, having its covered high-frequency range, must also cover the resonance frequency of the oscillating circuit formed, so that the latter for the duration of the emitted pulse is at some point excited in a resonant manner. After every chirped high-frequency pulse, in a transmission pause, the emission of electromagnetic radiation through the oscillating circuit is measured ("echo") by receiver 44 and the value of the emitted resonance frequency, i.e., of the resonance frequency of the oscillating circuit, which in turn is proportional to the lateral undercut to be determined, is measured using a standard frequency measuring method.

In a further exemplary embodiment, in an alteration of the exemplary embodiment discussed above, instead of a sequence of chirped high-frequency pulses, a sequence of broadband noise pulses is emitted from transmitter 43 to the surface of surface layer 23, i.e., pulses from a statistical frequency mix that includes the resonance frequency of the oscillating circuit formed on the basis of coil 30, delineated out on the silicon wafer. At the end of every noise pulse, in a transmission pause, the high-frequency output (the "echo") emitted by the LC

oscillating circuit, as described above, is then detected by receiver 44 and is evaluated in processing unit 40 with respect to its frequency. The oscillating circuit during the emission therefore takes on energy as soon as it is struck in its resonance frequency, energy that it subsequently emits once again on this frequency. During the pulse pauses, the re-emission ("echo") is particularly easy to detect because no strong transmission signal is superimposed.

In this exemplary embodiment, the resonance frequency or the change of the resonance frequency of the oscillating circuit as a physical measured quantity is also proportional to the extent, to be determined, of the lateral undercut.

Finally, it is also possible to emit a broadband noise spectrum continuously via transmitter 43 and to continuously detect it using transmitter 44. Since the emission of the LC oscillating circuit takes place in a narrow band around its resonance frequency, the superimposed transmission signal in this case can be reliably and simply separated from the emission of the LC oscillating circuit and can be identified.

Obviously, in addition to the resonance frequency of the oscillating circuit, an intensity, absorbed or emitted from the oscillating circuit, of an electromagnetic emission or a phase change in the radiation field, as a function of the undercut, are also suitable as physical measured quantities.

Patent Claims

1. A device for determining the extent of an at least locally lateral undercut of a structured surface layer (23) on a sacrificial layer (21),
characterized in that the structured surface layer (23) has locally at least one passive electronic component (31), using which a physical measured quantity can be determined which is proportional to the extent of the lateral undercut.

2. The device as recited in Claim 1,
characterized in that the physical measured quantity is a capacitance, an absorbed or emitted intensity of an electromagnetic emission, an absorbed or emitted frequency, in particular a resonance frequency, or an absorbed or emitted frequency spectrum of an electromagnetic emission.

3. The device as recited Claim 1,
characterized in that at least one transmitter (43) is provided, which emits a first signal, and at least one receiver (44) is provided, which detects a second signal, the passive electronic component (31) interacting with the first signal and, in this context, generating the second signal or transforming the first signal into the second signal.

4. The device as recited in Claim 3,
characterized in that the physical measured quantity can be determined from the second signal or from the difference between the first and the second signal.

5. The device as recited in Claim 3,
characterized in that the transmitter (43) and the receiver (44) are integrated in one assembly, in particular a processing unit (40), and/or that the transmitter (43) is at the same time also a receiver (44).

6. The device as recited in Claim 3,
characterized in that the first signal is a voltage applied to the passive electronic component (31); an intensity of an electromagnetic emission; a high-frequency power output, emitted continuously or in pulses and emitted into the passive electronic component (31), the high-

frequency power output having a preestablished frequency or preestablished frequency spectrum; or a sequence of chirped high-frequency pulses or broadband noise pulses of an electromagnetic emission, and that the second signal is an electrical voltage; an absorbed or emitted intensity of an electromagnetic emission; or a frequency, in particular a resonance frequency, or a frequency spectrum of an electromagnetic emission.

7. The device as recited in Claim 1,
characterized in that the passive electronic component (31) is a coil (30) delineated out in the surface layer (23), the coil having a first coil end (13) and a second coil end (12), the coil (30) along with a base layer (20) constituting a capacitor, the sacrificial layer (23) functioning as dielectric, the capacitance C of the capacitor being proportional to the extent, to be determined, of the lateral undercut of the surface layer (23).

8. The device as recited in Claim 7,
characterized in that the coil (30), together with its capacitance C, forms an oscillating circuit having a resonance frequency f_0, whose change Δf_0 is proportional to the extent, to be determined, of the lateral undercut of the surface layer (23).

9. The device as recited in Claim 7,
characterized in that a plated through-hole (22) is provided, which connects one of the coil ends (12, 13) to the base layer 20).

10. The device as recited in Claim 7,
characterized in that at least one of the coil ends (12, 13) is dimensioned in its extent such that a complete undercut of the coil end (12, 13) does not occur.

11. The device as recited in Claim 1,
characterized in that the structured surface layer (23), at least in the area of the passive electronic component (31), is separated from a base layer (20) by the sacrificial layer (21).

12. The device as recited in Claim 11,
characterized in that the base layer (20) is composed at least essentially of silicon or polysilicon, or it is a silicon wafer.

13. The device as recited in Claim 1,
characterized in that the surface layer (23), at least in the area of the passive electronic component (31), is at least weakly electrically conductive and is composed especially of silicon or polysilicon or of surface-metallized or doped silicon or polysilicon.

14. The device as recited in Claim 1,
characterized in that the sacrificial layer (21), at least in the area of the passive electronic component (31), is electrically insulating and is particularly composed of a silicon oxide layer.

15. The device as recited in Claim 1,
characterized in that the surface layer (23) is provided with trenches (15, 15') that extend in depth down to the sacrificial layer (21).

16. The device as recited in Claim 15,
characterized in that the trenches (15) border a structure (11), to be undercut, in the surface layer (23).

17. A method for determining the extent of the lateral undercut of a structured surface layer (23) on a sacrificial layer (21), in a first etching method the surface layer (21) being provided at least locally with a structure having trenches (15') and in a second etching method, beginning from the trenches (15'), a lateral undercut of the structured surface layer (23) being generated at least locally,
characterized in that in the first etching method at least one passive electronic component (31) is locally additionally delineated out of the surface layer (23), the component also being undercut in response to the undercut of the surface layer (23), and, in response to the undercut, a physical measured quantity proportional to the extent of the undercut being determined, using the component.

18. The method as recited in Claim 17,
characterized in that the structuring of the surface layer (23) takes place through a masking.

19. The method as recited in Claim 17,

characterized in that the sacrificial layer (21) is applied on a base layer (20).

20. The method as recited in Claim 17,
characterized in that the delineating out of the component (31) takes place through the etching of trenches (15).

21. The method as recited in Claim 17,
characterized in that a coil (30) is delineated out of the surface layer (23) as a passive electronic component (31).

22. The method as recited in Claim 21,
characterized in that in response to the undercut of the coil (30), the resonance frequency of an oscillating circuit formed on the basis of the coil (30) is measured, and the extent of the lateral undercut is determined therefrom.

Abstract

A device and a method are proposed for determining the extent of an at least locally lateral undercut of a structured surface layer (23) on a sacrificial layer (21). The structured surface layer (23) for this purpose locally has at least one passive electronic component (31), using which a physical measured quantity can be determined, which is proportional to the extent of the lateral undercut. The method according to the present invention for generating this device proposes, initially on the structured surface layer (23) in a first etching method, to provide the surface layer (21) at least locally with a structuring having trenches (15') and, in a second etching method, proceeding from the trenches (15'), to undertake at least locally a lateral undercut of the structured surface layer (23). In this context, in the first etching method on the surface layer (23), locally at least one passive electronic component (31) is additionally delineated out, which in response to a subsequent undercutting of the surface layer (23) is also undercut. The physical measured quantity is determined without contact, preferably by sending an electromagnetic emission into the passive component (31).

Figure 3

09/674984

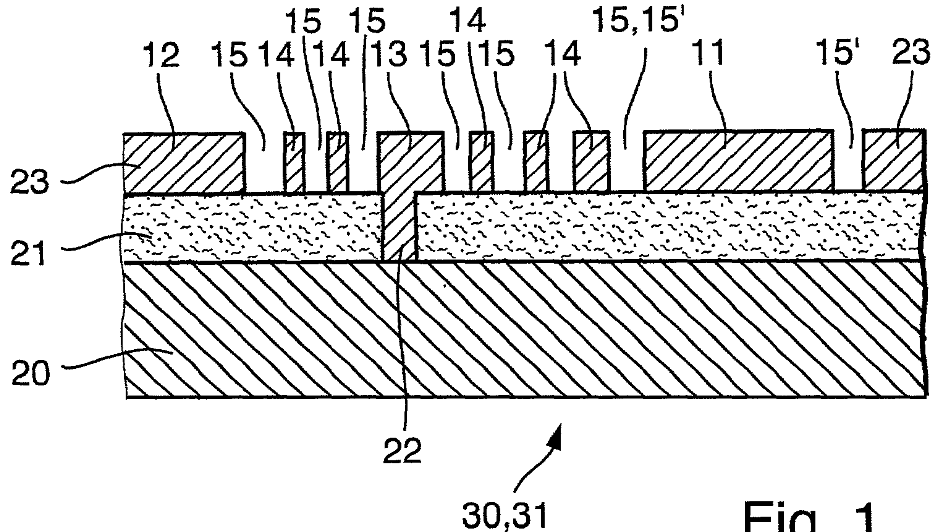

Fig. 1

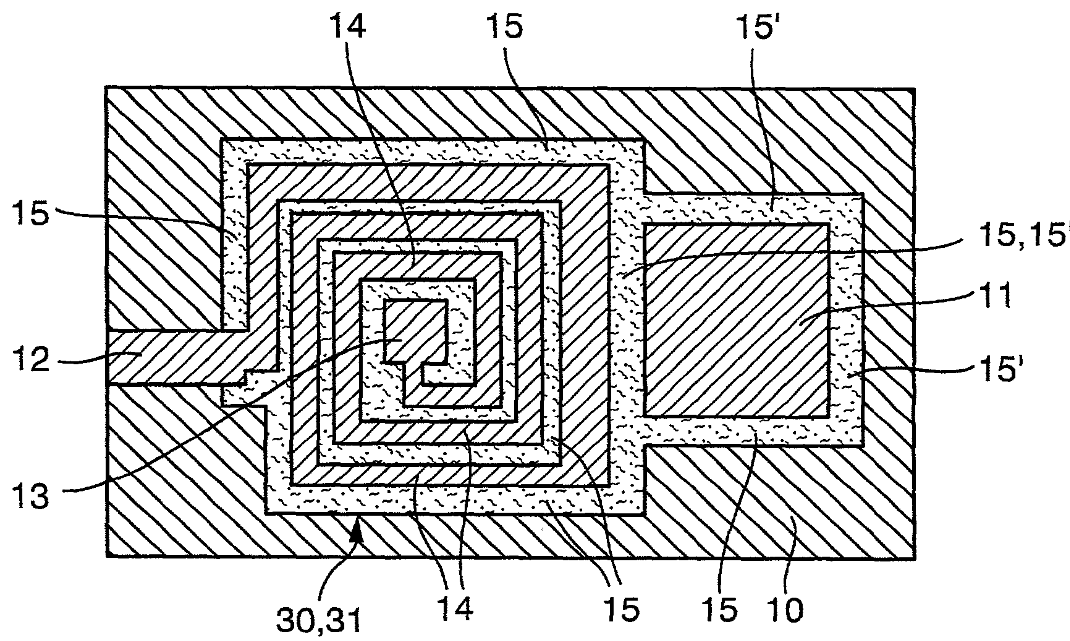

Fig. 2

09/674984

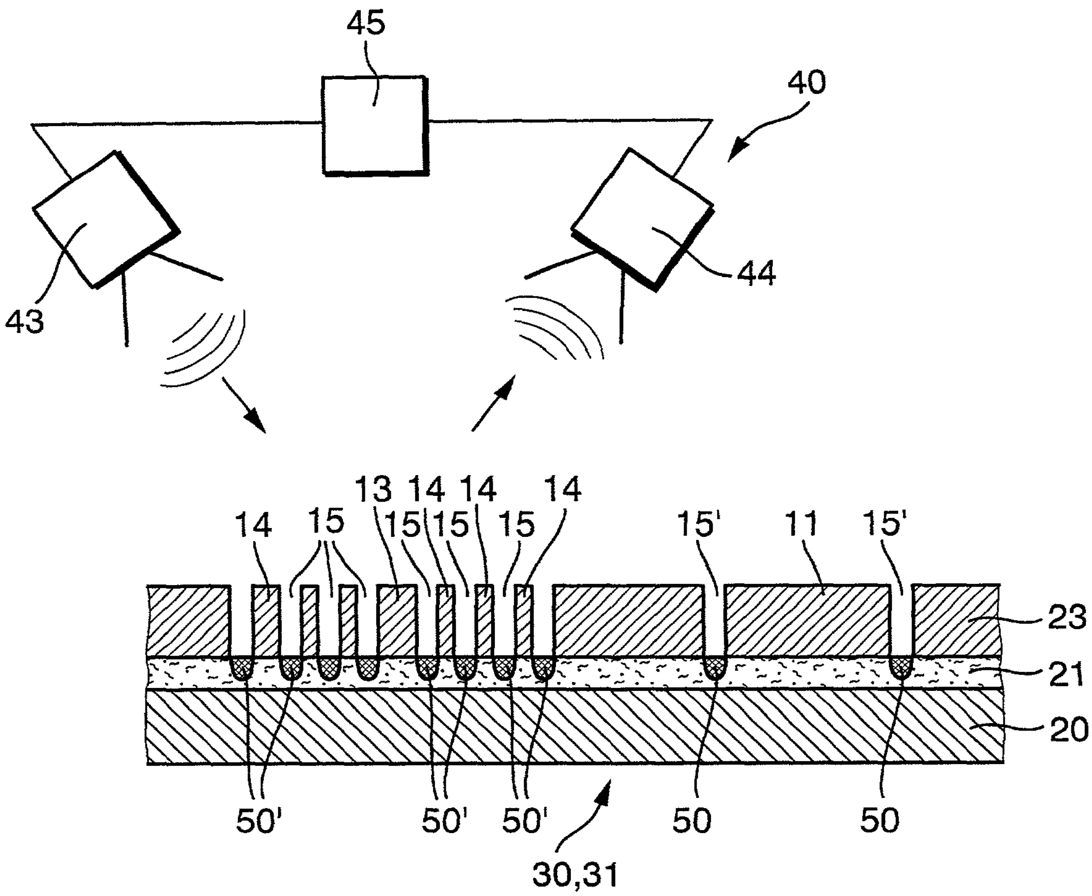

Fig. 3

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PRIOR FOREIGN APPLICATION(S)

Number	Country Filed	Day/Month/Year	Priority Claimed Under 35 USC 119
199 10 983.4	Fed. Rep. of Germany	12 March 1999	Yes

And I hereby appoint Richard L. Mayer (Reg. No. 22,490) and Gerard A. Messina (Reg. No. 35,952) my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful and false statements may jeopardize the validity of the application or any patent issued thereon.

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **A DEVICE AND METHOD FOR DETERMINING THE LATERAL UNDERCUT OF A STRUCTURED SURFACE LAYER**, the specification of which was filed as International Application No. PCT/DE00/00749 on March 13, 2000.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

EL594611206US